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PRE-OPERATIONAL TERRESTRIAL AND ATMOSPHERIC DEPOSITION STUDIES in the vicinity of the ONTARIO HYDRO THERMAL GENERATING STATION, ATIKOKAN, 1981 to 1985.

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PRE-OPERATIONAL TERRESTRIAL AND ATMOSPHERIC DEPOSITION STUDIES in the vicinity of the ONTARIO HYDRO THERMAL GENERATING STATION, ATIKOKAN, 1981 to 1985.

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INTRODUCTION

In 1978, Ontario Hydro began construction of a 200-megawatt lignite-fired thermal generating station 15 km (kilometres) north of the Town of Atikokan in northwestern Ontario.

Concerns were expressed about the effects of airborne emissions from this plant on ecologically sensitive areas such as Quetico Provincial Park in Ontario, and the Boundary Waters Canoe Area and Voyageurs National Park in northern Minnesota. In cooperation with Ontario Hydro and the Ontario Ministry of Natural Resources, a comprehensive environmental monitoring program began in 1979. In addition to some of the aquatic studies, the Ontario Ministry of the Environment was responsible for terrestrial and atmospheric deposition studies, both of which began in 1981. The purpose of these studies was to obtain three years of baseline data before the generating station was commissioned in 1985.

Preliminary Ministry reports on the terrestrial studies (1,2,3) revealed elevated levels of iron and arsenic in soil and in some types of vegetation near the power plant. Air emissions from two former operating iron ore pelletizing plants were responsible for this contamination.

This report summarizes all the pre-operational terrestrial and deposition data from 1981 to 1985. The generating station went into commercial service on November 14, 1985.

METHODS

TERRESTRIAL STUDIES

Fourteen vegetation and soil sampling sites were selected in May, 1981. In 1983, to improve the geographical distribution of sampling locations, another site was added at Bradshaw Lake. Prevailing wind direction, distance from the power plant, access,

proximity to air quality and precipitation sampling sites, and presence of suitable vegetation were factors considered in site selection.

The vegetation species included in the study fell into one or more of the following categories: commonly occurring, commercially important, important as wildlife browse, sensitive to air pollutants, or readily able to accummulate airborne contaminants. Sampling sites (Figure 1) were established on islands or shorelines of lakes, and were oriented to obtain maximum possible exposure to airborne contaminants emitted from the generating station. Standard Ministry procedures (4) were used to collect all samples. From those sites where present, foliage samples were collected annually from white birch (Betula papyrifera), current and one-year-old white pine (Pinus Strobus), beaked hazel (Corylus cornuta), mountain maple (Acer spicatum), and willow (Salix sp.). Feather moss (Pleurozium schreberi) and a foliose lichen (Umbilicaria muhlenbergii) were also sampled. Bark samples were obtained at a height of 1 to 1½ m (metres) from stems of white pine trees sampled for foliage from 1981 to 1983. The fruticose lichen Cladina rangiferina was collected in 1983 and 1984. Another lichen, Evernia mesomorpha, was also sampled in 1984. A partial list of lichens at several sites was compiled in 1984 and representative specimens of each species were collected. Three depths of soil (0-1, 1-2 and 2-5 cm) were collected from 1981 to 1984.

Trees and shrubs were tagged for sampling in future years. All vegetation and bark samples were analysed for aluminium, arsenic, cadmium, chloride, chromium, copper, fluoride, iron, lead, mercury, manganese, nickel, selenium, sodium, sulphur and zinc at the Ministry's laboratories in Thunder Bay and Toronto. In addition to the foregoing analyses, soil was analysed for calcium, loss on ignition, magnesium, phosphorus and potassium. Soil and bark pH were also determined.

To assess background levels of contaminants in air, dried Sphagnum moss in open-mesh polypropylene bags (4) was exposed for about 60-day periods during June and July in 1981, 1982 and 1983. Moss from this experiment was analysed for the same parameters as tree and shrub foliage.

Vegetation in the vicinity of designated study locations was examined annually for visible evidence of stress caused by disease, insects, contaminants or physiological factors.

Contaminant guidelines, developed by the Ministry of the Environment for vegetation, soil and moss, are used in this report. Their exceedence would suggest that contamination may be present, but would not necessarily imply adverse effects.

DEPOSITION STUDIES

As part of the Acidic Precipitation in Ontario Study (APIOS), the Ontario Ministry of the Environment operates precipitation sampling and air quality monitoring devices at several locations in northwestern Ontario. Cumulative (28-day) precipitation sampling began in the region in late 1980. Daily precipitation and air monitoring, and 28-day air sampling, began in late 1981. A description of the network and the monitoring methods used are published elsewhere (5,6).

There are three precipitation monitoring sites in the Atikokan area: Quetico Centre (30 km east-southeast of the generating station), Lac La Croix (70 km southwest), and Fernberg Road, Minnesota (95 km south). A fourth site, Forbes Township, is 135 km east of the generating station and serves as a "control" for comparison with data from the three sites closest to the power plant (Figure 2).

The snow profile was sampled in February, 1983 and in February, 1985 at the 15 sites shown in Figure 1. Standard Ministry collection and processing procedures were followed (4). Samples were analysed for the same parameters as vegetation, plus

calcium, carbon, conductivity, magnesium, phosphorus, potassium and residues. Parameter levels were compared with contaminant guidelines used by the Ministry.

RESULTS

VEGETATION AND SOIL

Tree and Shrub Foliage

No serious insect or disease problems were encountered during the study period at any of the sampling locations. Minor insect defoliation and skeletonizer injury were noted on trembling aspen, white birch, willow, beaked hazel, balsam poplar, and mountain maple. A severe mite infestation occurred on mountain maple at several sampling sites in 1983. There were no visible symptoms of air pollution injury to vegetation.

Chemical analysis results are presented in Table 1. Occasionally, contaminant guidelines were exceeded for arsenic, cadmium, chloride, nickel, sodium and sulphur. Most elements, however, were within normal background ranges. Levels of arsenic and iron were about a tenth of the concentrations recorded in deciduous and coniferous tree foliage when the two pelletizing plants were in operation in the 1970's (7).

White pine bark, Moss and Lichens

Elevated arsenic and iron were found at sites 1, 2, 4, 8, 11 and 12 in white pine bark, feather moss (Pleurozium schreberi), and the lichens Cladina rangiferina, Evernia mesomorpha, and Umbilicaria muhlenbergii (Table 2). The distribution of these elements in P. schreberi, plotted in Figures 3a and 3b, is similar to the patterns found in pine bark and in lichens. Bark, moss and lichens, in contrast to tree and shrub foliage, are exposed to airborne pollutants for many years.

Table 3 is a correlation matrix between pairs of elements in feather moss. While some of the significant positive correlations are between element pairs that naturally occur together (e.g.: chloride and fluoride), most reflect contamination from a common source. The data suggests that enrichment of arsenic, chromium, iron, manganese, selenium and zinc in feather moss are related to each other. The fact that most of these elements have a significant negative correlation with distance from the generating station suggests that their enrichment in feather moss was caused by the former iron mining activity. The relationships found between these elements in moss were absent in correlation matrices prepared for tree and shrub foliage, and for snow.

Data from the moss exposure experiment (Table 4) revealed that average parameter concentrations were low, and within the range expected in areas remote from pollution sources. The arsenic, cadmium and mercury guidelines were each slightly exceeded once in the three-year survey. The moss data show that current airborne levels of the elements tested are low and probably in compliance with Ministry regulations.

A partial list of lichen species at sites 1, 2, 4, 12 and 13 was presented in an earlier report (2). Lichen flora were luxuriant and diverse at most sites. At site 4 (Icy Lake), the older parts of Parmelia sulcata and P. flaventior plants were still strongly discoloured by iron oxide dust from the former iron mining operations. New growth in these lichens was normal in colour.

Soil

Chemical analysis results are summarized in Table 5. Average values for arsenic, mercury and iron are presented in Table 6. Arsenic, mercury and iron levels were usually highest in surface soils and decreased as soil depth increased. Although our sampling protocol was different from the standard depth (0-5 cm) used for contaminant guidelines, the data indicate that arsenic would have exceeded the guideline at sites 1, 2, 3, 4, 8, 9, 11 and 12. Similarly, the iron guideline would have been

exceeded at site 12 and the mercury guideline at sites 4, 5, 6, 9, 10, 11, 13 and 14. The distribution of average levels of arsenic and iron in 0-1 cm soil, plotted in Figure 4a and 4b, show patterns similar to those for the same elements in feather moss (Figures 3a and 3b). Above-normal concentrations of mercury were found in soil at most sites, but the distribution of the highest mercury levels was random and did not implicate point sources. The cause of the elevated mercury in soil is unknown. There were also occasional guideline exceedences in other parameters (Table 5), but most values were normal.

Determination of "enrichment factors" (8,9) and stable sulphur isotope ratios (10,11,12,13) have been reported as useful techniques for evaluating contamination effects around point sources. Their application to the Atikokan study was investigated and found to be unsuitable (1,2,3).

A correlation matrix for surface soil (Table 7) shows strong positive linear relationships between arsenic, chromium, iron, manganese, nickel and selenium. These relationships suggest-that these elements originated from a common source. The strong negative relationship between arsenic, chromium, iron and distance from the generating station is evidence that the source of these elements was emissions from the iron mines. These emissions may also have enriched aluminum, manganese, nickel and selenium levels in soils, as the negative relationships of their concentrations with distance from the power plant were nearly as strong as those for arsenic, chromium and iron.

ATMOSPHERIC DEPOSITION

Snowpack

Chemistry data from the 1983 and 1985 snow surveys are summarized in Table 8. The results reveal that all parameters were within background ranges expected in areas remote from pollution sources. Levels of arsenic and iron in snow were significantly lower than levels recorded when the iron mines were active in the 1970's (14).

Precipitation

Table 9 summarizes the 1982, 1983 and 1984 data for pH, sulphate, nitrate and ammonium at the four precipitation monitoring sites. Sulphates and nitrates account for most of the acidity in precipitation, while pH is a measure of the level of acidity itself. Ammonium is the dominant neutralizing agent in precipitation. Precipitation chemistry was similar at the four sites. For comparison, approximate sulphate, nitrate and ammonium concentrations are also shown in Table 9 for central and southern Ontario precipitation. Levels of the primary acidifying agents (sulphate and nitrate) were much lower in northwestern Ontario than in central and southern regions.

Airborne sulphur dioxide, sulphate, nitrate, nitric acid and ammonium were measured at Fernberg Road, Minnesota, from 1982 to 1984. Their average concentrations during this period were as follows: 1.1 $\mu g/m^3$ for sulphur dioxide, 1.4 $\mu g/m^3$ for sulphate, 0.03 $\mu g/m^3$ for nitrate, 0.12 $\mu g/m^3$ for nitric acid, and 0.33 $\mu g/m^3$ for ammonium. Levels of all these parameters were lower at Fernberg Road than in central and southern Ontario.

Table 10 shows the wet and dry deposition loadings for sulphur and nitrogen in the Atikokan area. As the table indicates, the deposition rates for northwestern Ontario are low, relative to central and southern Ontario. A wet sulphate deposition rate exceeding 20 kg/ha/year (about 7 kg/ha/year expressed as sulphur) may cause sensitive aquatic systems to be acidified. Table 8 indicates that sulphur loadings in northwestern Ontario are currently well below this figure.

SUMMARY AND DISCUSSION

Four years of pre-operational surveys around the Atikokan generating station have confirmed the presence of historical contamination of surface soils, lichens, feather moss and tree

bark. Significantly elevated levels of arsenic and iron, and slightly elevated concentrations of chromium, manganese, nickel, selenium and zinc were found in the terrestrial environment near the power plant. This contamination was caused by emissions from former iron ore mining operations which occurred over a 15-year period from the mid 1960's to about 1980. There was no clear trend of changes in arsenic and iron levels in soil or vegetation during the period of the pre-operational study. Contamination of the terrestrial environment around the Atikokan generating station is expected to persist for many years.

Moss exposure studies and chemical analysis of deciduous and coniferous foliage, snow pack and precipitation showed that atmospheric concentrations of all parameters examined were within normal background ranges. Deposition rates of sulphur and nitrogen compounds were much lower in the Atikokan area than in central or southern Ontario.

Mercury levels in the soil surface were higher than expected. The cause of elevated mercury is unknown, but point sources do not seem to be implicated.

To document any changes resulting from the operation of the thermal generating station, the monitoring studies outlined in this report will continue for at least the first three years of the operating life of the station. The data presented in this report will be used as a benchmark for comparison with data from the operational phase of the power plant.

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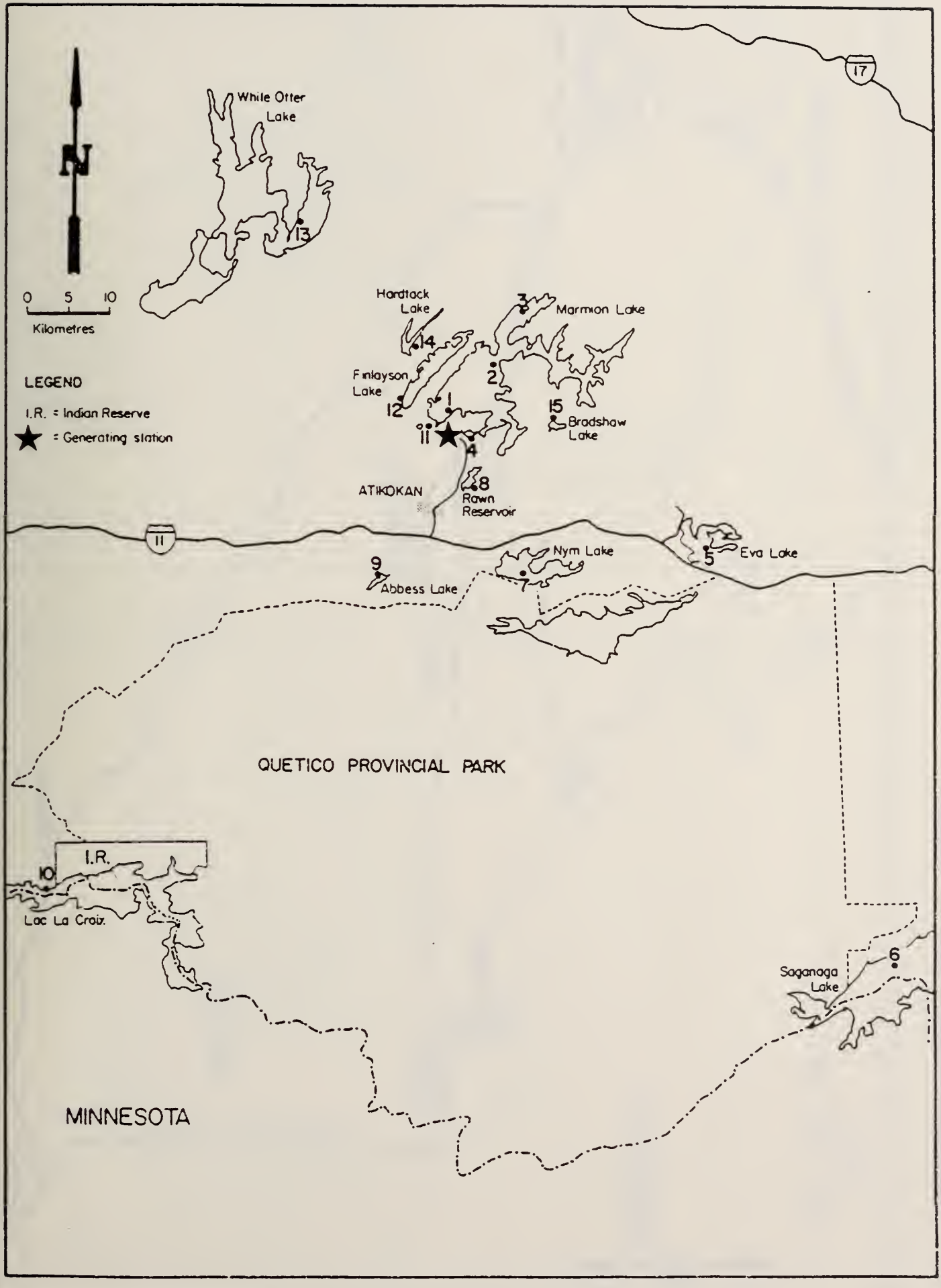

Figure 1. Vegetation, soil and snow sampling sites, Atikokan, 1981-85.

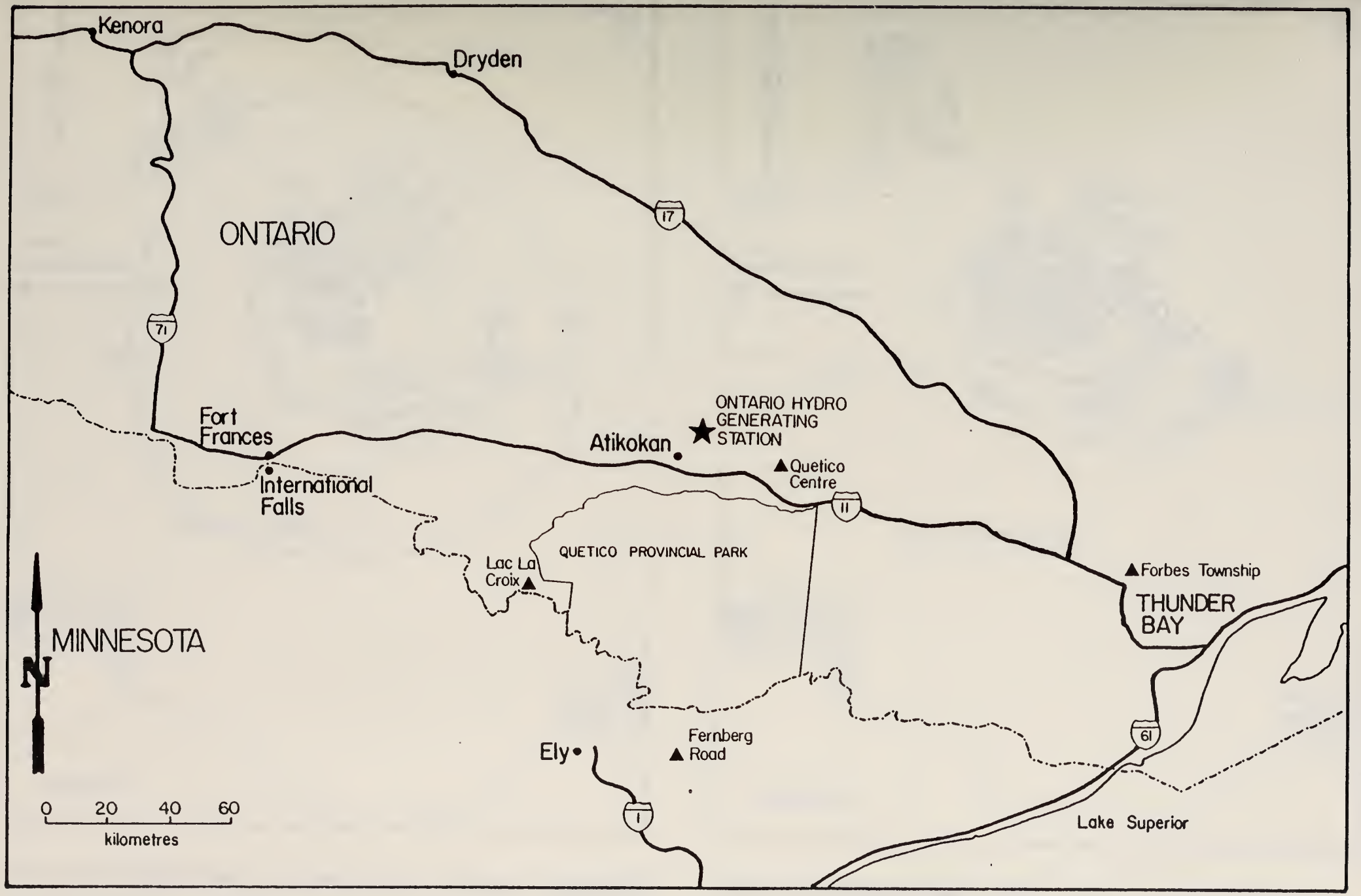

Figure 2. Precipitation sampling sites (▲), Atikokan.

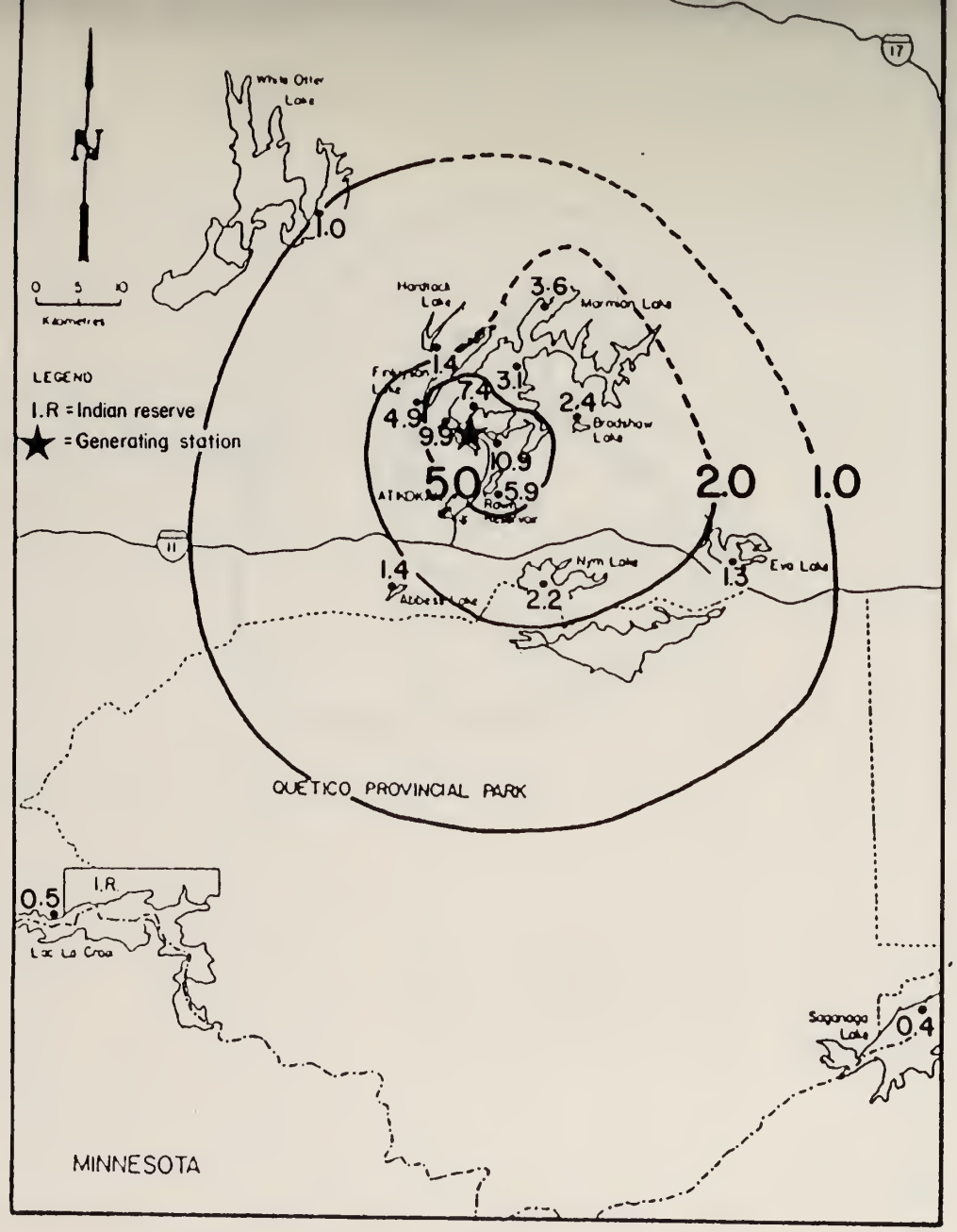

Figure 3a. Average levels of arsenic (µg/g, dry weight) in Pleurozium schreberi , Atikokan, 1981-83.

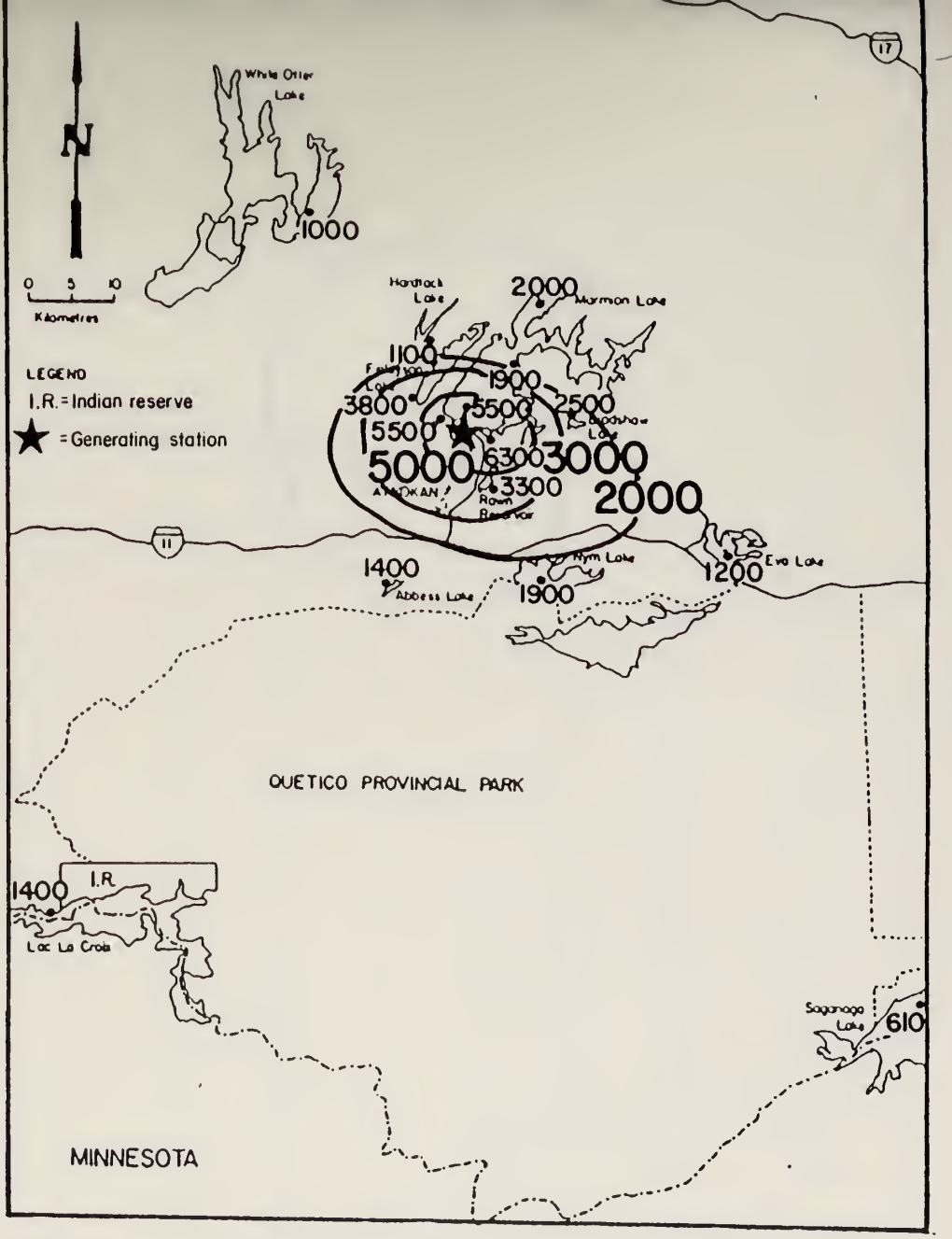

Figure 3b. Average levels of iron (µg/g, dry weight) in Pleurozium schreberi , Atikokan, 1981-83.

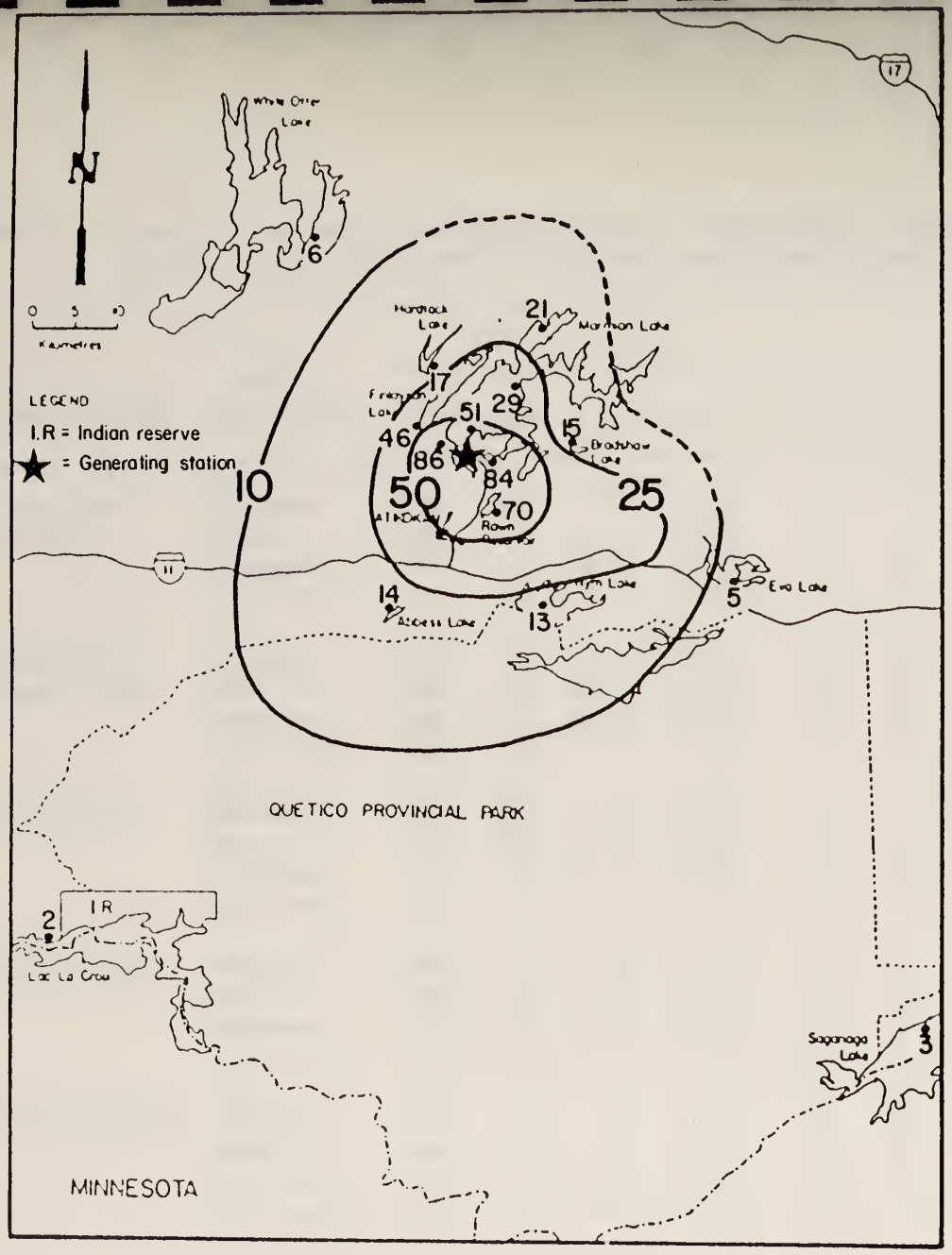

Figure 4a. Average levels of arsenic (µg/g, dry weight) in soil 0-1 cm, Atikokan, 1981-84.

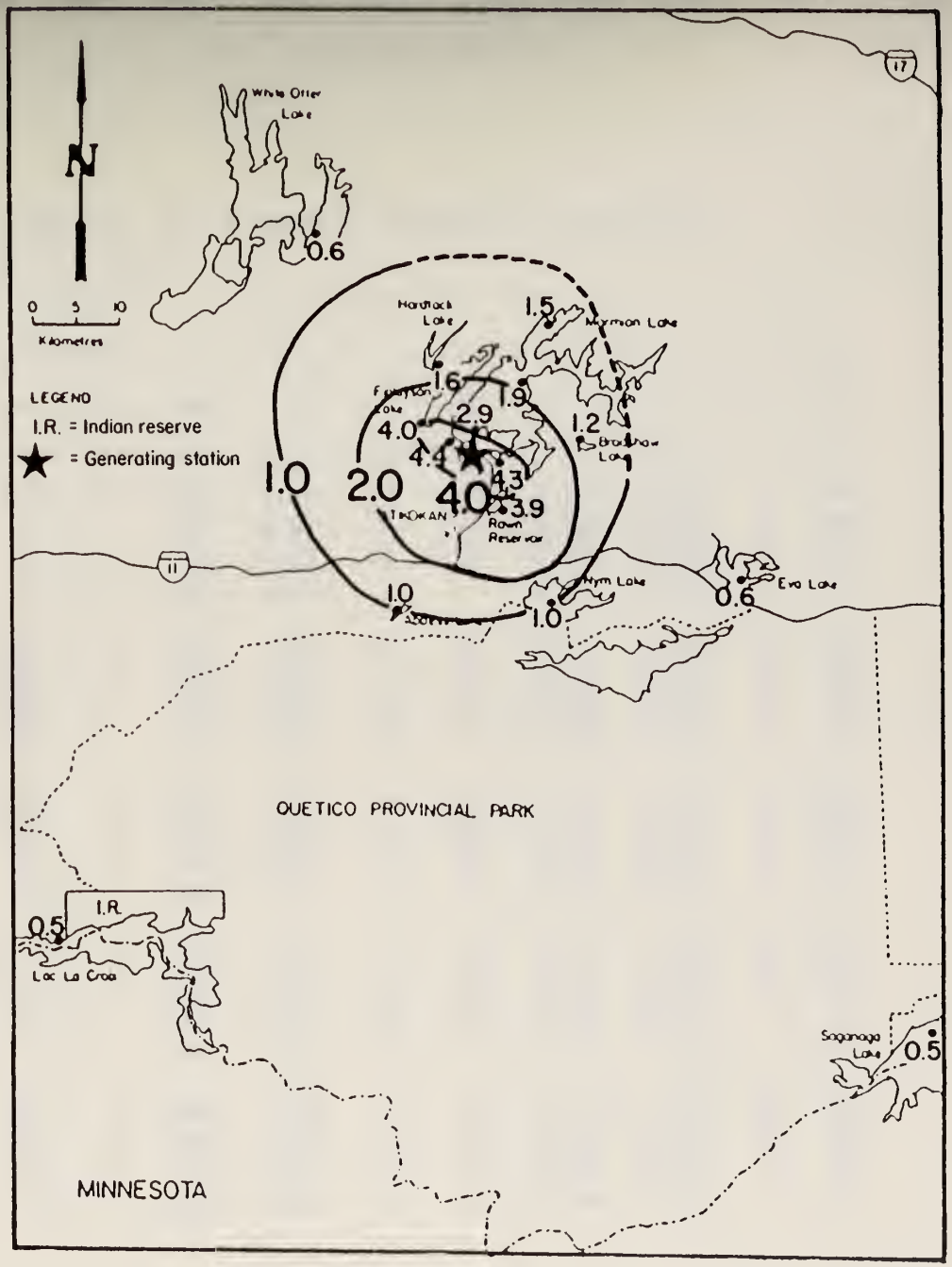

Figure 4b. Average levels of iron (percent, dry weight) in soil 0-1 cm, Atikokan, 1981-84.

TABLE 1. Levels of selected elements and pH in vegetation, Atikokan, 1981-83. All elemental values are in µg/g, dry weight, except chloride and sulphur, which are in percent, dry weight.

Plant species	Mean and range	Element																
		Al	As	Cd	Cl	Cr	Cu	F	Fe	Pb	Mn	Hg	Ni	Na	S	Se	Ti	Zn
White pine[a] (current)	Maximum	270	0.6	2.0	<0.10	6	6	14	320	6	470	0.08	11	50	0.15	0.58	4	64
	Mean	150	0.1	<0.5	0.03	<2	4	3	69	2	200	0.01	3	<25	0.09	0.13	2	34
	Minimum	60	<0.1	<0.5	<0.01	<2	2	<1	28	2	62	<0.01	<2	<25	<0.01	<0.03	1	19
	Std. dev.[b]	41	0.1	0.3	0.02	1	1	4	45	1	100	0.01	2	7	0.03	0.18	1	9
White pine[a] (1-year-old)	Maximum	1500	1.5	1.1	<0.10	11	4	19	490	5	870	0.09	7	45	0.11	0.46	10	76
	Mean	340	0.3	<0.5	0.02	<2	3	3	160	<3	370	0.02	2	<25	0.09	0.17	5	42
	Minimum	180	<0.1	<0.5	<0.01	<2	2	0	82	<3	92	<0.01	<2	<25	<0.01	<0.03	1	19
	Std. dev.	200	0.3	0.3	0.02	2	1	4	84	1	220	0.02	2	8	0.02	0.14	2	15
White birch	Maximum	200	2.3	2.0	<0.10	4	7	12	290	4	1600	0.05	6	110	0.17	0.20	4	270
	Mean	43	0.2	0.7	0.03	<2	5	4	96	2	760	0.01	<2	<25	0.10	0.09	3	120
	Minimum	10	<0.1	<0.5	<0.01	<2	2	1	47	2	80	<0.01	<2	<25	<0.01	<0.03	1	17
	Std. dev.	32	0.3	0.5	0.02	0.9	1	4	40	1	400	0.01	1	16	0.03	0.07	1	60
Beaked hazel	Maximum	180	0.4	1.0	0.10	3	8	10	230	6	2700	0.04	3	36	0.17	0.15	8	270
	Mean	98	0.2	<0.5	0.05	<2	6	3	119	<3	1500	0.01	<2	<25	0.12	0.05	4	39
	Minimum	26	<0.1	<0.5	<0.01	<2	4	<1	69	<3	760	<0.01	<2	<25	<0.01	<0.03	1	9
	Std. dev.	47	0.1	0.3	0.02	0.9	1	3	43	1	650	0.01	1	8	0.04	0.05	2	70
Mountain maple	Maximum	130	0.8	2.0	0.24	6	11	15	280	8	1000	0.09	3	69	0.21	0.37	11	63
	Mean	64	0.2	0.5	0.11	<2	6	3	117	2	550	0.02	<2	<25	0.13	0.12	4	33
	Minimum	15	<0.1	<0.5	<0.01	<2	4	0	62	<2	35	<0.01	<2	<25	<0.01	<0.03	2	13
	Std. dev.	27	0.2	0.5	0.05	1.3	2	4	49	2	280	0.02	1	13	0.04	0.12	3	13

TABLE 1. Continued.

Plant species	Mean and range	Element																
		Al	As	Cd	Cl	Cr	Cu	F	Fe	Pb	Mn	Hg	Ni	Na	S	Se	Ti	Zn
Willow	Maximum	180	2.4	3.8	0.10	8	8	13	250	15	620	0.08	12	43	0.41	0.60	5	180
	Mean	48	0.3	1.1	0.04	<2	5	3	120	3	210	0.02	3	<25	0.21	0.12	2	63
	Minimum	10	<0.1	<0.5	<0.01	<2	2	1	54	2	39	<0.01	<2	<25	0.10	<0.03	1	10
	Std. dev.	37	0.4	0.9	0.02	2	2	3	45	3	150	0.01	3	8	0.07	0.17	1	42
Pleurozium[a] schreberi (feather moss)	Maximum	1700	14.0	2.0	<0.10	24	16	22	9800	27	560	0.15	5	108	0.13	0.94	110	64
	Mean	920	3.8	0.5	0.02	5	5	6	2600	15	240	0.09	<2	41	0.09	0.51	62	32
	Minimum	80	0.2	<0.5	<0.01	<2	2	0	470	5	43	0.04	<2	<25	<0.01	0.19	9	15
	Std. dev.	310	3.7	0.4	0.02	4	2	8	2200	5	100	0.03	1	24	0.02	0.20	26	9
Cladina[a,c] rangiferina (lichen)	Maximum	1000	5.5	1.1	0.01	6.0	4	1.0	3300	12	120	0.09	6	76	0.05	0.86	82	23
	Mean	452	1.8	<0.5	<0.01	2.3	2	0.7	1089	5	45	0.04	<2	<25	0.03	0.19	47	15
	Minimum	220	0.3	<0.5	<0.01	<2.0	1	0.0	360	<3	18	0.02	<2	<25	<0.01	0.03	21	8
	Std. dev.	170	1.3	0.2	0.00	1.5	1	0.4	703	3	20	0.02	1	16	0.01	0.18	14	3
Evernia[a,d] mesomorpha (lichen)	Maximum	2200	25.0	0.8	0.03	15.0	9	2.0	1300	22	150	0.47	10	84	0.16	1.33	210	65
	Mean	1264	7.3	<0.5	0.02	4.8	4	1.1	3557	16	80	0.35	4	50	0.12	0.60	135	44
	Minimum	650	1.4	<0.5	<0.01	<2.0	2	1.0	1300	8	30	0.20	<2	<25	0.02	<0.03	81	26
	Std. dev.	457	7.0	0.2	0.01	4.2	2	0.3	3000	5	37	0.09	3	24	0.04	0.51	43	11
Umbilicaria[a] muhlenbergii (lichen)	Maximum	1800	29.0	1.5	0.25	19.0	14	42	13300	39	73	0.25	9	400	0.30	2.48	187	71
	Mean	1038	6.5	<0.5	0.03	5.9	4	6	3699	23	23	0.14	3	59	0.13	1.27	101	32
	Minimum	60	0.7	<0.5	<.01	<2.0	<2	0	810	9	12	0.08	<2	6	<0.01	0.53	20	14
	Std. dev.	316	6.5	0.3	0.04	4.6	2	9	2917	7	15	0.04	2	68	0.06	0.64	39	13

TABLE 1. Continued.

Plant species	Mean and range	Element																	
		Al	As	Cd	Cl	Cr	Cu	F	Fe	Pb	Mn	Hg	Ni	Na	S	Se	Ti	Zn	pH
White pine bark[a]	Maximum	1400	16.0	1.5	0.10	11.0	12	140	4800	32	130	0.26	8	130	0.10	2.4	106	51	4.0
	Mean	518	3.2	<0.5	0.02	2.4	4	10	1299	7	54	0.09	2	28	0.04	0.6	38	28	3.4
	Minimum	160	<0.1	<0.5	0.01	2.0	1	1.0	250	2	18	0.03	1	25	0.01	<0.03	10	11	2.9
	Std. dev.	275	3.8	0.3	0.02	2.4	2	21	1389	8	28	0.05	1	26	0.02	0.7	22	9	0.3
Contaminant guidelines[e]		500	2.0	1.0[f]	0.15	8.0	20	15	500	30	3000	0.10	5	50	0.40	0.5		250[f]	

[a] Contaminant guidelines do not apply.
[b] Standard deviation of the mean.
[c] Samples collected in 1983 and 1984.
[d] Samples collected in 1984 only.
[e] Applies to deciduous trees and shrub foliage only.
[f] Does not apply to accumulator species (willow and birch).

TABLE 2. Average levels[a] of arsenic and iron (µg/g, dry weight) in white pine bark, feather moss (*Pleurozium schreberi*) and in the lichens *Cladina rangiferina*, *Evernia mesomorpha*, *Umbilicaria muhlenbergii*, Atikokan, 1981 to 1984.

Site	White pine bark		*P. schreberi*		*C. rangiferina*		*E. mesomorpha*		*U. muhlenbergii*	
	Arsenic	Iron	Arsenic	Iron	Arsenic	Iron	Arsenic	Iron	Arsenic	Iron
1	11.9	3500	7.4	5500	2.4	1450	10.0	4600	11.9	9200
2	4.5	2200	3.1	1900	1.4	790	6.5	3000	7.9	3500
3	1.5	790	3.6	2000	2.5	950	14.0	4100	3.1	1900
4	5.6	2700	10.9	6300	4.2	1900			14.3	8500
5	0.5	430	1.3	1200	0.7	560	2.9	1800	1.9	1600
6	0.3	360	0.4	610	0.4	380	1.4	1300	1.4	1000
7	0.8	360	2.2	1900	1.2	620	3.6	2000	3.5	2700
8	8.1	3400	5.9	3300	2.3	1000	14.0	4800	8.0	4600
9	0.6	350	1.4	1400	0.9	920	1.6	2100	2.3	2000
10	0.5	510	0.5	1400	0.4	670	1.6	2600	0.8	1600
11	2.9	610	9.9	5500	4.4	2200	25.0	13000	21.7	6000
12	5.7	2500	4.9	3800	3.1	2300	13.0	4900	5.6	3500
13	0.5	330	1.0	1000	0.8	1200	1.8	1500		
14	1.3	400	1.4	1100	1.6	840	4.2	2500	3.4	2400
15[b]	1.2	520	2.4	2500	1.1	540	2.8	1600	3.7	1800

[a] All values are averages of three years of sampling (1981-83) except for *C. rangiferina* (1983 and 1984) and *E. mesomorpha* (1984).

[b] Station 15 (Bradshaw Lake) was not sampled in 1981 and 1982.

TABLE 3. Correlation matrix of selected elements in feather moss (Pleurozium schreberi), Atikokan, 1981-83.

	Al	As	Cd	Cl	Cr	Cu	F	Fe	Pb	Mn	Hg	Ni	Se	Na	S	Zn
As	.28															
Cd	.11	-.02														
Cl	.02	.13	.46*													
Cr	.39	.71*	.01	.12												
Cu	.29	.40*	-.10	.36	.33											
F	.25	.12	.38	.86*	.37	.42*										
Fe	.41*	.91*	-.01	.10	.59*	.42*	.09									
Pb	.20	.19	.23	.14	.35	.20	.14	.10								
Mn	.27	.51*	.16	.29	.26	.51*	.30	.56*	.10							
Hg	.35	.34	-.02	.24	.27	.22	.36	.29	.31	.15						
Ni	.18	.37	.18	.11	.07	.37	-.03	.36	.25	.30	.13					
Se	.15	.73*	.05		.45*	.18	.13	.57*	.11	.45*	.49*	.00				
Na	.02	.05	-.13	.00	.02	.00	.16	.03	-.13	.05	.19	.08	-.11			
S	.05	.27	.26	.45*	.36	.28	.53*	.16	.41*	.23	.34	-.02	.46*	-.15		
Zn	.30	.43*	.01	-.11	.48*	.31	.00	.42*	.36	.40*	.30	.05	.45*	.02	.22	
Distance From G.S.	-.28	-.59*	.01	.01	-.38*	-.39	.08	-.52*	-.14	-.53*	-.05	-.28	-.67*	.15	-.17	-.46*

*Denotes a significant Pearson correlation for pairs of elements at P <0.01.

TABLE 4. Concentrations of selected elements in Sphagnum moss exposed from June to July, 1981 to 1984[a]. Values are in µg/g, dry weight, except those for chloride and sulphur, which are in percent, dry weight.

Mean and range	Al	As	Cd	Cl	Cr	Cu	F	Fe	Pb	Mn	Hg	Ni	Na	S	Zn
Maximum	1500	1.10	2.5	<0.10	7.5	6	100	1700	26	410	0.40	6	240	0.29	62
Mean	1000	0.51	<0.5	0.02	2.7	4	12	1121	13	212	0.10	2	80	0.05	39
Minimum	430	<0.10	<0.5	<0.01	<2.0	2	0	760	5	99	0.05	<2	25	0.01	30
Std. dev.[b]	284	0.30	0.4	0.02	1.9	1	20	252	5	68	0.06	1	59	0.05	8
Contaminant guidelines[c]	1700	1.00	2.0	0 .03		8	45	1700	35		0.20	6	250	0.60	100

[a] Exposure period each year was approximately 60 days.
[b] Standard deviation of the mean.
[c] Based on a 30-day exposure period.

TABLE 5. Levels of selected elements and pH in three depths of soil, Atikokan, 1981-84. All elemental values are in µg/g dry weight, except aluminum, calcium, chloride, magnesium, potassium and sulphur, which are in percent, dry weight.

	Al	As	Cd	Ca	Cl	Cr	Cu	F	Fe	Pb	Mg	Mn	Hg	Ni	P	K	Se	Na	S	Zn	Ti	pH
Soil (0-1 cm)																						
Maximum	2.1	150	4.0	2.6	0.10	140	720	360	7.7	370	1.2	3800	0.82	86	3.3	0.20	6.08	390	0.27	360	4500	5.8
Mean	0.7	31	1.0	.8	0.03	32	73	61	2.0	58	0.2	921	0.27	14	1.1	0.10	1.56	103	0.11	87	1411	4.6
Minimum	0.1	1.4	<0.5	.3	<.01	3	8	3	0.3	10	0.1	32	0.02	<2	0.1	0.08	<0.03	19	0.02	23	260	3.3
Std. dev.	0.3	33.4	0.8	.4	0.02	26	121	57	1.7	45	0.1	981	0.15	14	0.5	0.03	1.62	79	0.05	58	1127	0.6
Soil (1-2)																						
Maximum	2.8	87.0	3.0	1.9	0.10	120	240	380	5.1	97	2.4	4100	2.40	51	2.1	0.22	3.68	450	0.24	272		6.3
Mean	1.0	13.5	0.9	0.6	0.03	25	47	67	1.4	38	0.3	497	0.21	11	0.9	0.13	1.08	123	0.10	56		4.4
Minimum	0.3	1.4	<0.5	0.2	0.01	5	6	3	0.2	5	0.1	26	<0.01	<2	0.2	0.05	<0.03	<25	0.02	13		3.2
Std. dev.	0.5	14.5	0.7	0.3	0.02	20	58	63	1.1	18	0.3	847	0.32	11	0.4	0.03	0.98	78	0.05	44		0.7
Soil (2-5 cm)																						
Maximum	4.2	56.0	3.5	1.5	0.10	150	330	450	6.7	70	3.0	3900	0.57	70	2.5	0.24	2.39	390	0.16	162		5.8
Mean	1.2	7.5	0.8	0.4	0.02	30	46	77	1.4	22	0.3	326	0.12	13	0.7	0.11	0.68	158	0.07	45		4.3
Minimum	0.2	0.5	<.5	0.1	<0.01	2	3	2	0.3	<3	0.1	19	<0.01	<2	0.1	0.03	<0.03	<25	0.01	6		2.9
Std. dev.	0.7	9.5	0.7	0.2	0.02	30	68	77	1.2	18	0.5	698	0.13	15	0.5	0.05	0.71	87	0.05	35		0.6
Contaminant guideline for 0-5 cm soil[a]		10	4.0	3.0		50	60			150	1.0	1000	0.15	60			2.00		0.10	500		

[a]Applies only to 0-5 cm soil.

TABLE 6. Average levels[a] of arsenic and mercury (µg/g, dry weight) and iron (percent, dry weight) in three depths of soil, Atikokan, 1981-1984.

Site	Arsenic			Mercury			Iron		
	0-1 cm	1-2 cm	2-5 cm	0-1 cm	1-2 cm	2-5 cm	0-1 cm	1-2 cm	2-5 cm
1	51	15	5	.24	.10	.03	2.9	1.5	1.5
2	29	8	8	.23	.11	.08	1.9	1.3	1.3
3	21	14	9	.18	.09	.04	1.5	1.4	1.9
4	84	30	11	.54	.22	.23	4.3	1.6	0.8
5	5	5	3	.24	.74	.22	0.6	0.5	0.5
6	3	3	3	.23	.27	.24	0.5	0.6	0.5
7	13	4	2	.11	.11	.08	1.0	0.9	1.3
8	70	18	10	.22	.15	.04	3.9	1.4	1.4
9	14	10	7	.37	.24	.21	1.0	1.3	1.3
10	2	2	2	.23	.18	.13	0.5	0.5	0.4
11	86	43	43	.27	.23	.16	4.4	2.6	1.5
12	46	28	20	.15	.12	.04	4.0	3.9	4.1
13	6	4	2	.29	.22	.12	0.6	0.6	0.6
14	17	9	4	.27	.21	.10	1.6	1.8	2.7
15[b]	15	8	6	.23	.11	.08	1.2	0.9	0.3
Contaminant guideline[c]		10			0.15			3.5	

[a] Values for arsenic, mercury and iron are averagés of four years of sampling.
[b] Station 15 (Bradshaw Lake) was not sampled in 1981 and 1982.
[c] Applies to 0-5 cm soil.

TABLE 7. Correlation matrix of selected elements in 0-1 cm soil, Atikokan, 1981-84.

	Al	As	Cd	Cl	Cr	Cu	F	Fe	Pb	Mn	Hg	Ni	Se	Na	S	Zn
As	.07															
Cd	.04	-.08														
Cl	-.04	.09	.53*													
Cr	.44	.72*	.15	.10												
Cu	.07	.29	.01	.27	.22											
F	.19	-.03	.08	.09	.13	-.23										
Fe	.19	.92*	.00	.07	.77*	.32	.01									
Pb	-.08	.20	.10	.18	.10	-.07	.07	.26								
Mn	.01	.52*	.14	.02	.36	-.03	.03	.45	.39							
Hg	-.33	.45	-.16	-.01	.09	.03	.02	.28	.14	.37						
Ni	.21	.60*	.14	.05	.66*	.27	.02	.77*	.62*	.41	.02					
Se	-.17	.73*	.03	.20	.56*	.16	.06	.74*	.31	.34	.56*	.54*				
Na	.73*	.06	-.17	-.17	.33	.03	.09	-.12	-.17	-.12	-.36	.15	-.27			
S	-.27	.19	.28	.04	.38	.17	.30	.30	.19	.16	.32	.37	.48	-.43		
Zn	-.08	.50*	.04	.19	.28	.24	-.02	.39	.23	.76*	.31	.25	.24	-.11	.27	
Distance from G.S.	-.39	-.57*	-.09	.04	-.56*	-.22	.08	-.57*	-.10	-.40	-.05	-.43	-.43	-.23	.09	-.22

*Denotes a significant Pearson correlations for pairs of elements at P <0.01.

TABLE 8. Concentrations of selected parameters in meltwater from snow collected in February, 1983 and February, 1985. All elemental values are in µg/ℓ, except for carbon and suspended solids (in mg/ℓ) and conductivity (in µmhos/cm).

Parameter	Maximum	Mean	Minimum	Standard deviation	Guideline
Aluminum	130	50	8	27	600
Arsenic	2	<1	<1	0.3	40
Cadmium	1	0.6	0.1	0.3	3
Calcium	610	170	<100	130	2000
Chloride	<100	<100	<100	0	4000
Chromium	3	<2	<2	0.5	
Cobalt	<2	<2	<2	0	
Copper	2	<1	<1	0.4	60
Fluoride	<100	<100	<100	0	
Iron	130	51	24	20	700
Lead	6	<3	<3	2	70
Magnesium	170	<70	<70	40	400
Manganese	11	3	1	2	
Mercury	<0.05	<0.05	<0.05	0	0.1
Nickel	2	<2	<2	0.3	40
Phosphorus	8	3	<1	2	40
Potassium	170	<40	<40	30	1000
Selenium	<1	<1	<1	0	
Sodium	550	<200	<200	130	2000
Sulphate	1500	950	470	370	3000
Titanium	10	3	<1	3	
Vanadium	<1	<1	<1	0	
Zinc	6	2	<1	1	300
Residue filtrate	12	8	3	3	
Residue particulate	5	2	1	0.9	30
Residue total	17	11	6	3	
Dissolved inorganic carbon	<0.2	<0.2	<0.2	0	
Dissolved organic carbon	1.7	0.5	0.2	0.3	
Total particulate carbon	1.2	0.6	0.0	0.3	
Conductivity	25	13	6	6	60
pH	5.9	4.7	4.2	0.5	

TABLE 9. Average precipitation pH[a] and concentrations (mg/ℓ)[b] of sulphate, nitrate and ammonium in precipitation at four sites in northwestern Ontario, 1982-84[c].

Parameter and year		Quetico Centre	Lac La Croix	Fernberg Road	Forbes Township	Central Ontario	Southern Ontario
pH	1982	4.9	5.0	5.0	4.8	~4.3	~4.2
	1983	5.3	5.1	5.3	5.0	~4.4	~4.4
	1984	5.2	4.8	5.3	5.2	~4.3	~4.4
SO_4	1982	1.1	1.3	1.0	1.3	~3.0	~4.0
	1983	0.9	0.9	0.9	1.2	~3.0	~3.5
	1984	0.9	1.1	1.2	1.4	~2.6	~3.1
NO_3	1982	0.2	0.2	0.2	0.2	~0.4	~0.6
	1983	0.1	0.2	0.2	0.2	~0.4	~0.6
	1984	0.2	0.4	0.2	0.2	~0.5	~0.5
NH_4	1982	0.2	0.3	0.2	0.3	~0.4	~0.3
	1983	0.2	0.2	0.3	0.2	~0.5	~0.4
	1984	0.2	0.1	0.3	0.2	~0.3	~0.4

[a]Arithmetic means.
[b]Volume-weighted means.
[c]See references 15, 16, 17.

TABLE 10. Estimated wet and dry deposition rates of sulphur and nitrogen (kg/ha/year) near Atikokan, and in central and southern Ontario, 1982 and 1983[a].

Area	Sulphur		Nitrogen in Nitrate	
	Wet[b]	Dry[c]	Wet	Dry
Atikokan area	4.0	0.7	2.0	0.8
Central Ontario	6.0-8.0	1.5-2.5	3.0-4.0	2.0-3.0
Southern Ontario	8.0-14.0	2.0-6.5	4.0-6.0	2.0-3.0

[a]See references 18, 19, 20.
[b]Sulphur in sulphate.
[c]Sulphur in sulphur dioxide and sulphate.

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